REPORT

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System Impact Assessment Report (Addendum)

Raleigh
Wind Generation Station (WGS)

CONNECTION ASSESSMENT & APPROVAL PROCESS

CAA ID 2007-268

Final Report

Applicant: Invenergy Wind Canada ULC and its affiliate Raleigh Wind Power Partnership

Market Facilitation Department

June 17, 2010

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System Impact Assessment Report

Raleigh Wind Generation Project

Acknowledgement

The IESO wishes to acknowledge the assistance of Hydro One in completing this assessment.

Disclaimers

IESO

This report has been prepared solely for the purpose of assessing whether the connection applicant's proposed connection with the IESO-controlled grid would have an adverse impact on the reliability of the integrated power system and whether the IESO should issue a notice of approval or disapproval of the proposed connection under Chapter 4, section 6 of the Market Rules.

Approval of the proposed connection is based on information provided to the IESO by the connection applicant and the transmitter(s) at the time the assessment was carried out. The IESO assumes no responsibility for the accuracy or completeness of such information, including the results of studies carried out by the transmitter(s) at the request of the IESO. Furthermore, the connection approval is subject to further consideration due to changes to this information, or to additional information that may become available after the approval has been granted. Approval of the proposed connection means that there are no significant reliability issues or concerns that would prevent connection of the proposed facility to the IESO-controlled grid. However, connection approval does not ensure that a project will meet all connection requirements. In addition, further issues or concerns may be identified by the transmitter(s) during the detailed design phase that may require changes to equipment characteristics and/or configuration to ensure compliance with physical or equipment limitations, or with the Transmission System Code, before connection can be made.

This report has not been prepared for any other purpose and should not be used or relied upon by any person for another purpose. This report has been prepared solely for use by the connection applicant and the IESO in accordance with Chapter 4, section 6 of the Market Rules. The IESO assumes no responsibility to any third party for any use, which it makes of this report. Any liability which the IESO may have to the connection applicant in respect of this report is governed by Chapter 1, section 13 of the Market Rules. In the event that the IESO provides a draft of this report to the connection applicant, you must be aware that the IESO may revise drafts of this report at any time in its sole discretion without notice to you. Although the IESO will use its best efforts to advise you of any such changes, it is the responsibility of the connection applicant to ensure that it is using the most recent version of this report.

HYDRO ONE

Special Notes and Limitations of Study Results

The results reported in this study are based on the information available to Hydro One, at the time of the study, suitable for a preliminary assessment of a new generation or load connection proposal.

The short circuit and thermal loading levels have been computed based on the information available at the time of the study. These levels may be higher or lower if the connection information changes as a result of, but not limited to, subsequent design modifications or when more accurate test measurement data is available.

This study does not assess the short circuit or thermal loading impact of the proposed connection on facilities owned by other load and generation (including OPG) customers.

In this study, short circuit adequacy is assessed only for Hydro One breakers and does not include other Hydro One facilities. The short circuit results are only for the purpose of assessing the capabilities of existing Hydro One breakers and identifying upgrades required to incorporate the proposed connection. These results should not be used in the design and engineering of new facilities for the proposed connection. The necessary data will be provided by Hydro One and discussed with the connection proponent upon request.

The ampacity ratings of Hydro One facilities are established based on assumptions used in Hydro One for power system planning studies. The actual ampacity ratings during operations may be determined in real-time and are based on actual system conditions, including ambient temperature, wind speed and facility loading, and may be higher or lower than those stated in this study.

The additional facilities or upgrades which are required to incorporate the proposed connection have been identified to the extent permitted by a preliminary assessment under the current IESO Connection Assessment and Approval process. Additional facility studies may be necessary to confirm constructability and the time required for construction. Further studies at more advanced stages of the project development may identify additional facilities that need to be provided or that require upgrading.

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RALEIGH WIND GENERATION PROJECT
IESO SYSTEM IMPACT ASSESSMENT (ADDENDUM)

1. Introduction

Invenergy Wind Canada ULC and its affiliate Raleigh Wind Power Partnership are developing a new 78 MW wind power generation farm in Chatham. The project was awarded a contract under the government RES III, and is expected to start commercial operation in January 7, 2011.

The Raleigh WGS will be connected to Hydro One's 230 kV circuit C23Z via a new 230 kV interconnection substation located adjacent to the right-of-way, approximately 12 km along circuit from Chatham switching station (SS).

The System Impact Assessment for Raleigh WGS was completed (CAA ID 2007 - 268) on November 27, 2009. Recently, the connection applicant (CA) has submitted a modified design of the Raleigh WGS to the IESO. The number of feeders is to be reduced from four to two in the WGS with the same total number of wind turbines. The originally and new proposed connection arrangements are shown in Figure 1 and Figure 2, respectively.

This assessment examined the impact of injecting 78 MW of wind power generation to the provincial grid on the reliability of the IESO-controlled grid with the proposed changes.

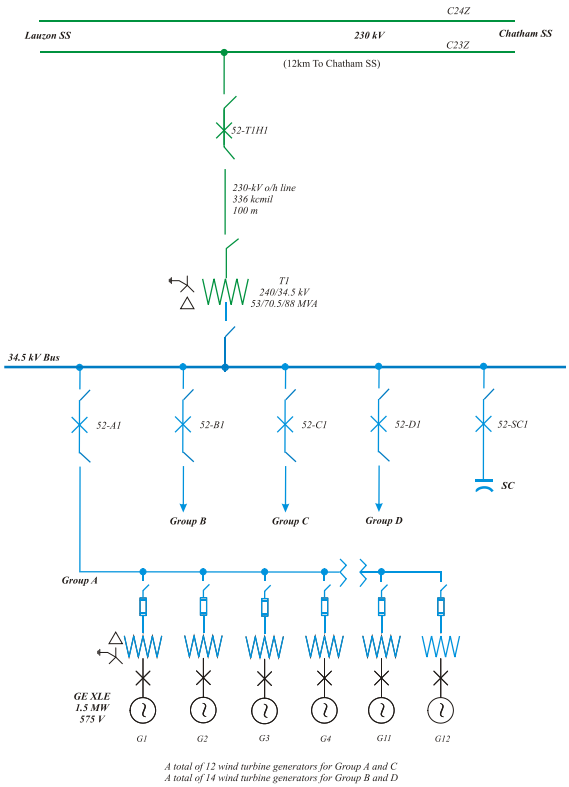

Figure 1: Originally Proposed Raleigh WGS

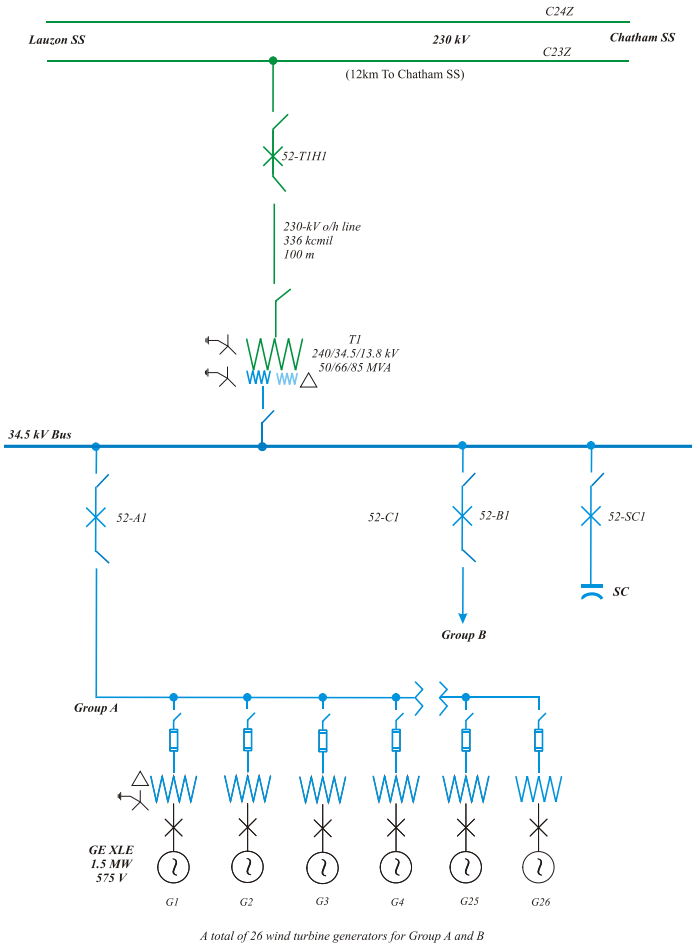

Figure 2: New Proposed Raleigh WGS

2. Data Verification

The applicant provided updated information on the step-up transformer and collector system.

2.1 Transformer

Specifications for the 34.5/230 kV step-up transformer are listed below.

Transformation	240/34.5/13.8 kV
Rating	50/66/85 MVA ONAN/ONAF/ONAF
Impedance	0.09 pu based on 50 MVA
Configuration	3 phase, Wye-grounded/Wye-grounded/Delta
Tapping	on-load tap changers at HV (240±8*1.25%)

It should be noted that the applicant updated the configuration of the transformer with Wye-grounded/Wye-grounded/Delta. Hydro One accepted the grounded HV wye configuration conditional to receiving a blocking transfer trip signal for an internal fault within Raleigh network system. The IESO concluded that the grounded HV wye configuration will not have adverse impact on the reliability of the IESO-controlled grid

2.2 Collector System

The 34.5 kV collector system equivalent circuit impedances as well as charging provided by the connection applicant are listed as follows:

Feeder #	Equivalent Impedance (Ohm)	Equivalent Impedance (pu)	Charging (MVAr)
1	0.669+j2.477	0.056+j0.208	2.056
2	0.506+j1.673	0.043+j0.141	1.750

Per unit data are based on 100 MVA & 34.5 kV.

3. Reactive Power Compensation

Based on the information provided by the applicant, the IESO concluded that the proposed changes will not have significant impact on the system reliability except that the requirements for the reactive power compensation need to be reassessed.

Market Rules require that generators inject or withdraw reactive power continuously (i.e. dynamically) at a connection point up to 33% of its rated active power at all levels of active power output except where a lesser continually available capability is permitted by the IESO. Therefore, the Raleigh WGS should have a capability of injecting/absorbing at least **25.7** MVAr at the 230 kV connection point.

The MR accepts that a generating unit with a power factor range of 0.90 lagging and 0.95 leading at rated active power connected via a main output transformer impedance not greater than 13% based on generator rated apparent power provides the required range of dynamic power at the connection point. As indicated in the SIA report (CAA ID 2007 – 268 dated November 27, 2009), the proposed wind turbine generators (WTG) have adequate dynamic reactive power capability, thus there is no need to install any additional dynamic reactive compensation.

Typically, the impedance between the WTG and the connection point is larger than 13%. However, provided the WTG has the capability to provide a reactive power range of 0.90 lagging power factor and 0.95 leading power factor at rated active power, the IESO accepts the WGS to compensate for the full reactive power requirement range at the connection point with switchable shunt admittances (e.g. capacitors and reactors).

This section of the SIA indicates how the WGS can meet the MR requirements regarding reactive power capability, but the CA is free to deploy any other solutions which result in its compliance with the MR.

It is the CA's responsibility to ensure that the WGS has the capability to meet the MR requirement at the connection point and be able to confirm this capability during the commission tests.

Load flow studies were performed to justify a need for static reactive compensation based on the equivalent parameters for the WGS provided by the connection applicant in Section 2.

3.1 Inductive Reactive Power Compensation

The PTI software was used to verify the reactive power capability in leading p.f. of the generation facility, with the following assumptions:

- Typical voltage of 242 kV at the connection point;

- Minimum active power output from the WGS;
- Maximum reactive power consumption from the WTG, unless limited by the minimum acceptable WTG terminal voltage;
- Minimum WTG voltage of 0.9;
- The main step-up transformer ULTC is available to adjust the LV voltage within acceptable range (98% - 106%), but as close as possible to 1 pu.

The simulation results in Figure 3 showed that the generation facility can absorb a maximum reactive power of **41 MVAr** at the connection point, indicating that Raleigh WGS meets the reactive power in leading p.f. requirement.

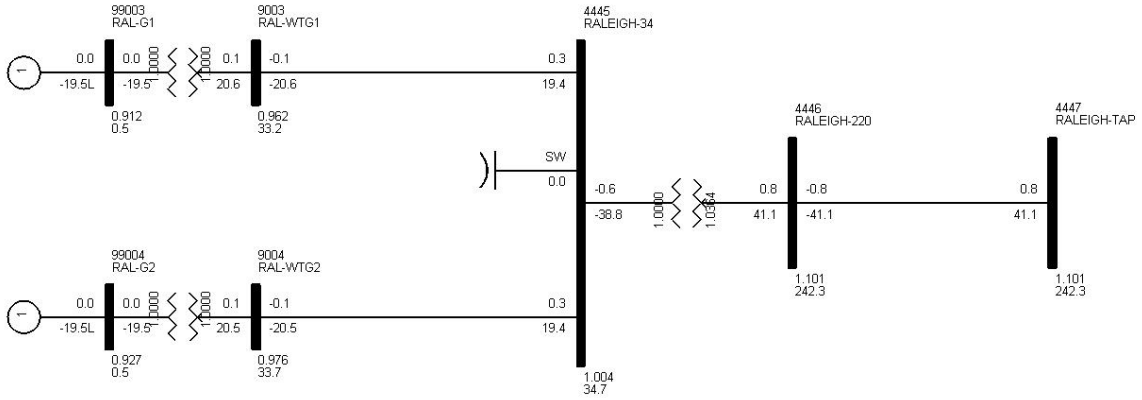

Figure 3: Results for Inductive Capability Test

3.2 Capacitive Reactive Power Compensation

Simulations were performed to determine the static capacitive compensation requirements, with the following assumptions:

- Typical voltage of 242 kV at the connection point;
- Maximum active power output from the WGS;
- Maximum reactive power output from the WTG, unless limited by the maximum acceptable WTG terminal voltage;
- Maximum WTG voltage of 1.1, as per the WTG voltage capability;
- The main step-up transformer ULTC is available to adjust the LV voltage within acceptable range (98% - 106%), but as close as possible to 1 pu.

The results in Figure 4 show that the generation facility can supply a maximum reactive power of **18.3 MVAr** at the connection point. This indicates that static reactive compensation is required to be installed at the collector bus to meet the reactive power in lagging p.f. requirement.

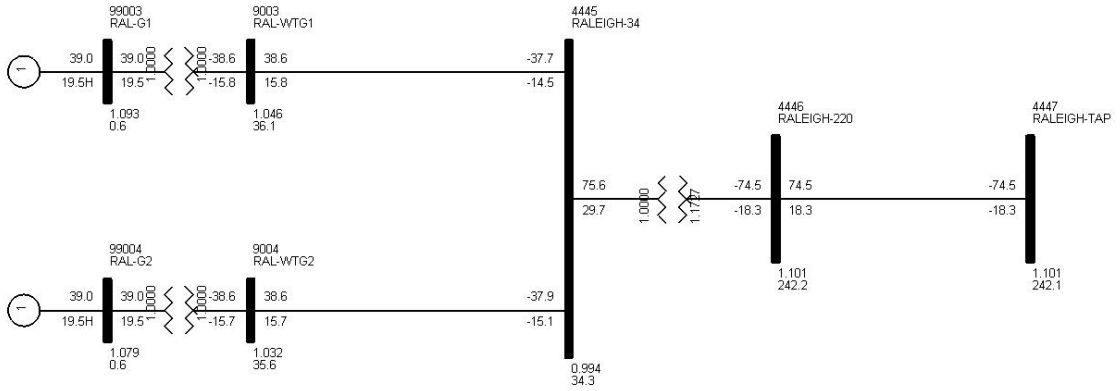

Figure 4: Results for Capacitive Capability Test – Before Compensation

As shown in Figure 5, one capacitor bank, with a capacity of **9 MVAr@34.5 kV,** installed at the 34.5 kV bus will increase the reactive power injection at the connection point. With this capacitor bank, the wind farm can supply a maximum reactive power of **+25.9 MVAr** at the connection point, which meets the capacitive reactive power requirement**.**

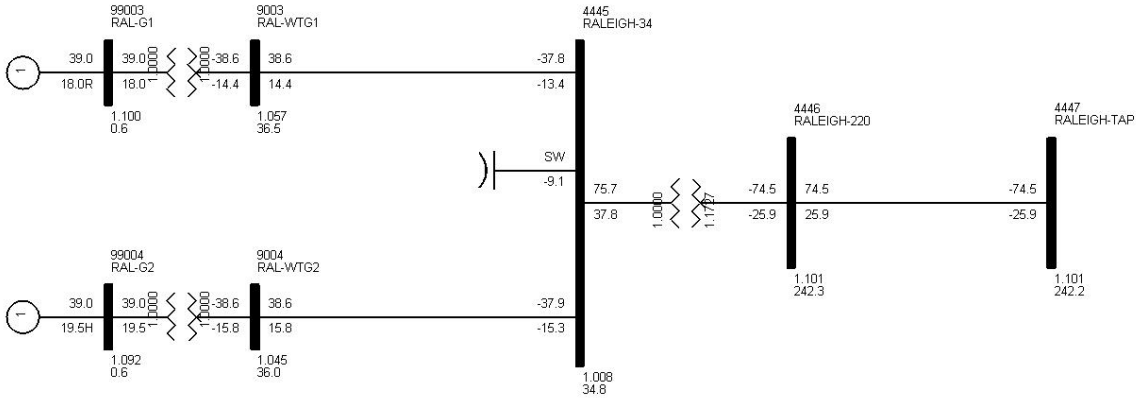

Figure 5: Results for Capacitive Capability Test – After Compensation

The IESO's reactive power calculation used the equivalent electrical model for the WTG and collector feeders as provided by the CA. It is very important that the WGS has a proper internal design to ensure that the WTG are not limited in their capability to produce active and reactive power due to terminal voltage limits or other facility's internal limitations. For example, it is expected that the transformation ratio of the WTG step up transformers will be set in such a way that it will offset the voltage profile along the collector, and all the WTG would be able to contribute to the reactive power production of the WGS in a shared amount.

Based on the equivalent parameters for the WGS provided by the connection applicant, an amount of 9 MVAr of static reactive power compensation is required to be installed at the WGS collector bus to meet the reactive power requirements at the connection point.

The connection applicant has the obligation to ensure that the WGS design and the reactive power compensation system takes into account the real electrical parameters and real limitations within the WGS facility.

3.3 Static Reactive Power Switching

Switching study was carried out to investigate the effect of switching the new LV shunt capacitor bank on the voltage changes.

Following summarizes the change in voltage due to switching of a single capacitor of 9 MVAr at the collector bus. All generators in the study case are treated as fixed source currents injecting into the network and the load boundary conditions are converted from the conventional constant MVA characteristic to a voltage dependent load model. No automatic adjustments are allowed, and switched shunt devices and transformer tap settings are locked at their pre-switching settings.

LV			HV		
PRE	**POST**	**%**	**PRE**	**POST**	**%**
34.7	35.1	1.15	242.3	242.7	0.16

The IESO allows ΔV on a single capacitor switching to be no more than 4 %. Study results show that switching of a single capacitor of 9 MVAr produces less than 4% voltage increase.

4. Wind Farm Management System

If the generation facility connects to the IESO-controlled grid, the IESO requires that the facility assists maintaining voltage in the high voltage system. It is expected that the wind farm controls the voltage at a point as close as possible to the connection point to values specified by the IESO. This requires that wind farms possess the ability to supply sufficient dynamic reactive power to the high voltage system during voltage declines.

The proponent submitted a description of the functionalities of the WFMS. The document indicated that the WFMS is designed with the capability to coordinate and control fixed capacitor banks when the total VAR requirements for the farm cannot be supplied by the reactive capability of the wind turbines themselves. The VAR banks are coordinated to preserve the dynamic range of the WTG output by switching in first to meet the base VAR demand of the farm. Therefore, the IESO concluded the proposed control scheme meets the requirements.

5. Conclusions

The findings of this analysis are summarized as follows:

(1) The connection impedance between the wind turbine generators and the IESO-controlled grid exceeds the limit derived from Market Rules requirements, resulting in reactive power deficiency. To compensate for this deficiency reactive compensation devices have to be installed.
(2) Study results show that switching of a single capacitor of 9 MVAr produces less than 4% voltage increase.

6. Requirements for Connection

This System Impact Assessment concludes that the modifications to the Raleigh WGS will result in change of reactive power compensation requirements.

- Based on the equivalent parameters for the WGS provided by the connection applicant, an amount of 9 MVAr of static reactive power compensation is required to be installed at the WGS collector bus to meet the reactive power requirements at the connection point.
- The connection applicant has the obligation to ensure that the WGS design and the reactive power compensation system takes into account the real electrical parameters and real limitations within the WGS facility.
- The proponent must submit a description of the functionalities of the WFMS, including the coordination between the automatic capacitor switching and generator reactive power production to control the voltage at a desired point. This document also must contain the settings of the automatic capacitor switching scheme. If the WFMS is unavailable, the IESO requires each generator controls its own terminal voltage.

7. Notification of Approval

It is recommended that Notification of Conditional Approval for connection be issued to the connection applicant, subject to IESO's Requirements for Connection listed above and in the initial SIA report (issued on November 27, 2009), and any further requirements that may be identified by Hydro One Networks Inc. in the Customer Impact Assessment.